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A WATER STRATEGY FOR THE DOMESTIC AND INDUSTRIAL WATER SUPPLY TO NORTH JORDAN

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In Collaboration With
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INTRODUCTION

North Jordan which may be taken as extending from the southern limits of the Wadi Mujib and Azrab catchments northwards to the Syrian border, covers an area of 49 000 km^2. Within this area lies Amman the capital city and commercial centre of the country and Irbid the focal point of agricultural development in the north.

For many years now the ever increasing demands for water for municipal and industrial use have exceeded the local resources on which the main towns once relied and it has been necessary to look further afield and draw from resources which hitherto have been considered the reserve of agriculture. The Jordanian Government has recently put in hand studies to determine the total water resources of the country (Ref. 1) and to develop a strategy which would ensure the best use of the limited water resources for domestic and industrial supplies in North Jordan while at the same time, safeguarding agricultural development especially in the Jordan Valley (Ref. 2). This latter study suggests that available resources will be insufficient for the foreseen needs for domestic use, industry and agriculture well before the end of the centure and poses the problem as to which sectors should suffer restraints on their increasing consumption and the forms that these restraints should take.

WATER BALANCE

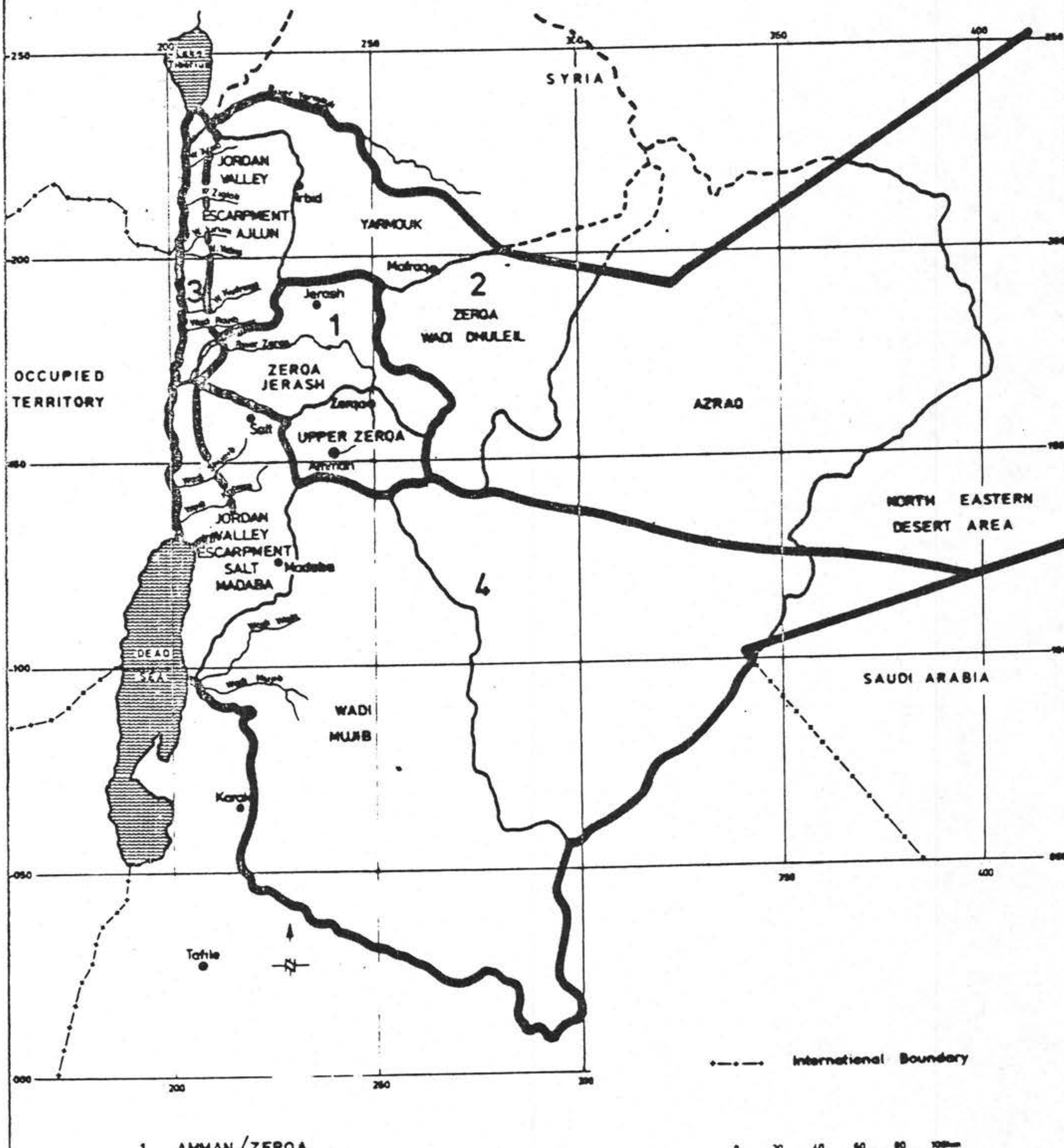
In order to determine the scope of the problem it is useful to consider the water balance over the whole of North Jordan for the next 25 years and for this purpose it is convenient to divide the area into four districts as shown schematically in Figure 1 namely:;

1. Amman Zerqa district.
2. The northern district extending from Irbid in the west to Azraq in the east and including Wadi Dhuleil.
3. The Jordan Valley.
4. Southern district including all towns and villages not included in the foregoing areas.

Ref. 1: Agrar and Hydrotechnik GmbH "National Water Master Plan for Jordan" 1977.

Ref. 2: Howard Humphreys and Sons "Water Use Strategy North Jordan" 1978.

KEY PLAN



1 AMMAN/ZERQA
2 NORTHERN DISTRICT
3 JORDAN VALLEY
4 SOUTHERN DISTRICT

Table 1 summarises the estimated population by areas for the years 1977, 1987 and 2002 and the corresponding domestic and industrial demands projections for the same years are shown in Table 2.

TABLE 1 - Population Projections

District	Population (1000's)		
	1977	1987	2002
Amman Zerqa district	1076	1625	2906
Northern district	463	573	786
Jordan Valley	75	148	247
Southern district	200	213	279
Totals	1814	2559	4218

TABLE 2 - Domestic and Industrial Water Demand Projections

District	Demand (Mm^3/a)		
	1977	1987	2002
Amman Zerqa district	57	107	230
Northern district	16	24	40
Jordan Valley	1	4	8
Southern district	6	11	11
Totals (Mm^3/a)	80	146	289

Assuming no limit on available water, agricultural requirements for the same periods by the same districts can be summarised as follows:-

TABLE 3 - Agricultural Water Requirements

District	Water Requirements (Mm^3/a)		
	1977	1987	2002
Amman Zerqa district	49	49	49
Northern district	89	80	80
Jordan Valley	194	411	407
Southern district	47	96	96
Totals (Mm^3/a)	379	636	632

The total estimated requirements for domestic use, industry and agriculture are therefore:-

1977: 459 Mm^3/a
1987: 782 Mm^3/a
2002: 921 Mm^3/a

Looking now at the water available to meet these requirements the total resources which could be exploited as groundwater are estimated to be as follows:-

TABLE 4 - Summary of Estimated Exploitable Ground Water Resources

Area	Resources (Mm^3/a)
Sama Sdoud	5
Azraq	10
N.E. desert	5
Dhuleil	20
Amman-Zerqa	20
Baqa'a	2
Qastal	5
Qatrana	1
Siwaqa	2
Sultani	4
Total	74 Mm^3/a

These cover only replenishable resources and so exclude mining potential.

The total surface water resources for the principal catchments are estimated to have mean annual values as indicated in Table 5.

TABLE 5 - Summary of Estimated Surface Water Resources

Area	Resources (Mm^3/a)
Yarmouk (at Adasiya)	390
Azraq	10
Zerqa (at Deir Alla)	67
Ajlun	72
Salt-Madaba	68
Mujib	76
Total	683 Mm^3/a

These resources are summarised graphically in Figure 2.

The groundwater and surface water resources are not independent and ground water abstractions in the Amman Zerqa aquifers have their effects on the base flow component of the surface discharge in that catchment. Similarly an abstraction of more than 10 Mm^3/a from the Azraq aquifers would reduce the amount which could safely be taken from the pools. Allowance has been made for these interrelationships in compiling the above tables and the totals give a reasonable estimate of the total resources available from both. If adequate surface storage were provided it would be possible to utilise about 550 Mm^3/a of the surface resources, the balance being wasted as flood flows so that the total natural replenishable resources which could be exploited in North Jordan is about 624 Mm^3/a.

When these are compared with the projected demands it is immediately apparent that the latter will exceed the available supplies by the mid 1980's. Indeed the planned agricultural requirements alone will soon exceed the resources.

RE-USE OF WATER

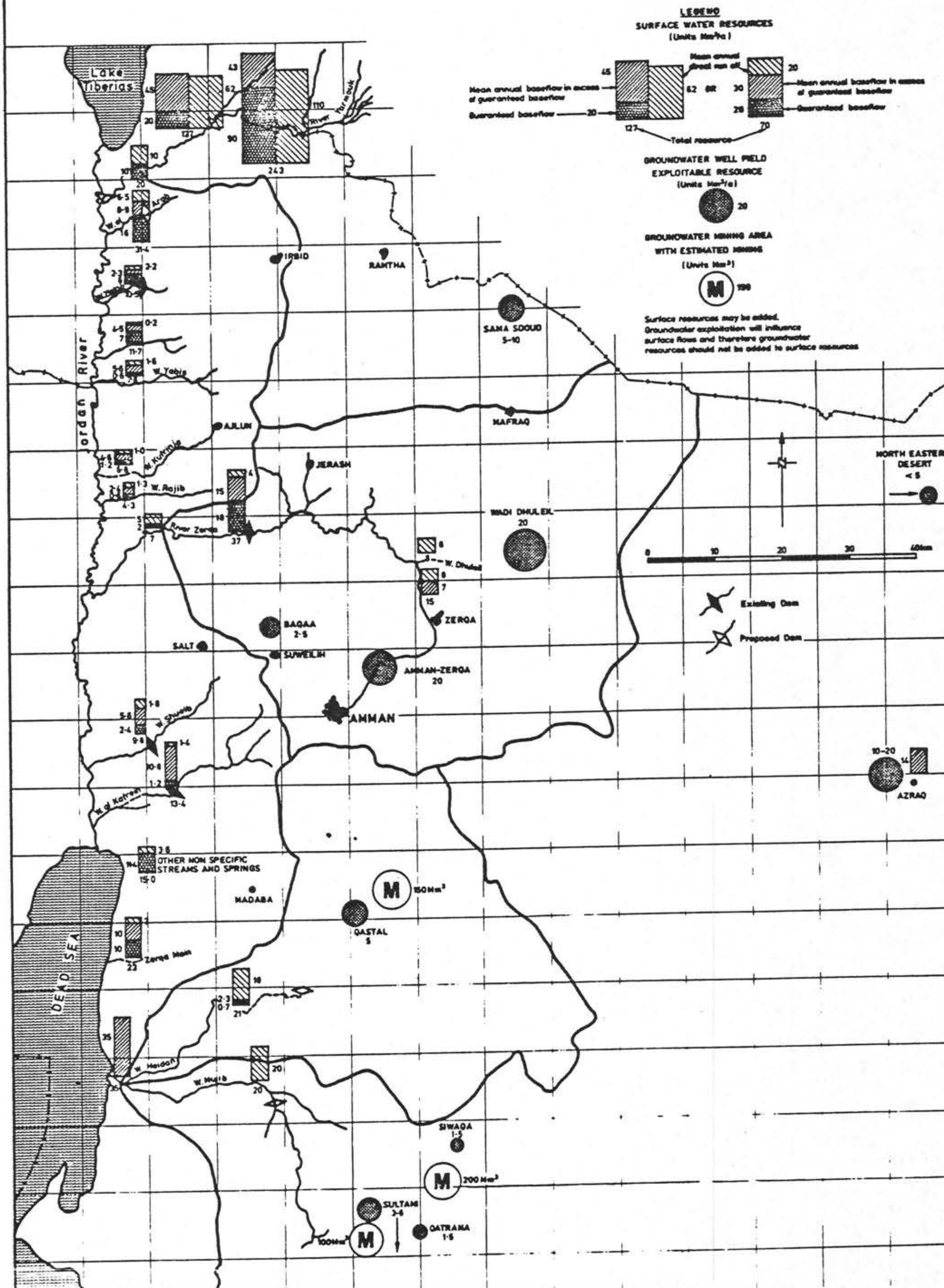
In considering the balance between demand and available resources however the re-use of water must also be taken into account. Re-use of water, intentional or otherwise has now been common practice for many years and it is becoming increasingly rare in heavily populated areas of the world for communities to draw on a water resource which has not been polluted to some extent by upstream users.

However, only recently as the ever increasing demand outstrips the fixed resources available, has there been a deliberate policy of re-use and a growing appreciation of the need for much greater control over pollution, particularly industrial.

Re-use can take the form of direct re-cycling of waste water after some form of treatment and its use has been common particularly in agriculture where quality considerations are less rigorous. Only in the past few years has the need arisen in some parts of the world for the direct re-use of

Figure. 2

WATER RESOURCES



waste water for drinking supplies and recent work has shown that it is possible, following a rigorous chemical and physical processing, to produce a water to the exacting standards necessary for drinking. Much however has to be learnt about the dangers of such a practice, techniques of both treatment and quality control are still being developed and there can be no room for error. In Jordan the need has not yet arisen for such measures.

Indirect re-use occurs when waste water is returned to a water course where the effects of sunlight, dilution and natural purification improve the quality of the water to an acceptable standard . Alternatively waste water from septic tanks or surplus water from irrigation finds its way ultimately into the ground water supplies where natural filtration can produce a potable water. In North Jordan the principal return to the cycle will be in the Amman Zerqa area and an appreciation of the factors involved is important in trying to assess the possible benefits to be obtained.

RECYCLING IN THE AMMAN ZERQA BASIN

Of the water used for domestic or industrial purposes in Amman, a proportion is lost by evaporation or transpiration and the remainder is discharged as waste into sewers or septic tanks. The sewered areas drain to the treatment works where the effluent is discharged into the Wadi Seil finally entering the newly constructed King Talal reservoir as surface flow. Discharge into septic tanks soaks away into the ground; a proportion may emerge as springs along the wadis in the city, particularly during wet conditions, but most of it returns to ground, mixing with natural recharge in the Amman area and travelling with the general groundwater movement along the Zerqa Valley. It is likely that a large proportion of this return to groundwater is abstracted by the many borehole pumps along the wadi bed and that the flow past the pumps will eventually enter the King Talal reservoir where, except for a proportion lost by deep seepage, it will be impounded.

The proportion recovered to the cycle as effluent from the works is easy to assess but is not significant at present as only a small part of the town is sewered. Current consumption in Amman is about 17 Mm^3/a of which only about 4 Mm^3/a passes through the works. It is however very difficult to make an estimate of the amount returned to groundwater and of the time required for these returns to enter the groundwater system, although the response of the springs to rain suggests that this time is not unduly long.

In considering the water balance then, we are concerned not so much with the actual usage of water, part of which is returned to the cycle, but rather with the water that is lost altogether. There are no quantitative measurements of these losses but if it is taken as 50% the inference is that all water from whatever source imported into Amman can be used twice - or alternatively that the net resource required to meet the demand is only half of the demand.

Returns to groundwater from irrigation are likely to be very much less and within the context of this discussion have been neglected.

WATER BALANCE REVIEWED

Returning now to the water balance, it will be recalled that the total water requirements for the years 1987 and 2002 are estimated at 782 and 921 Mm^3/a respectively which compares with the total natural replenishable resource of 624 Mm^3/a. If the recovery of waste from Amman is assumed to be 50% of the usage then the net requirements to be satisfied can be assessed thus:-

TABLE 6 - Net Water Requirements for Amman-Zerqa

	Requirements (Mm^3/a)	
	1987	2002
50% of demand from Amman-Zerqa	54	115
Other domestic and industrial demands	38	59
Total municipal demand	94	175
Agricultural requirements	636	632
Total net requirements	728	806

It will be seen that even by 1987 the net requirements will have exceeded the exploitable replenishable resource and that by 2002 the net deficit will have risen to over 180 Mm^3/a. It is clear that urgent policy decisions are needed in order to determine those areas in which growth or consumption can or should be limited.

LIMITATIONS OF GROWTH

Limitations to growth in the consumption of water may be possible in a number of ways. Of the total quantity used for domestic purposes as much as 50% is used for water borne sanitation and some saving in this field is possible. However, in Amman, where domestic consumption is greatest some of this is already recovered and once the city is sewered a large percentage of this waste will in any case be returned after treatment, to the cycle.

In most distribution systems, considerable losses, amounting to 25% and even more in many cases, occur as leakage from faulty pipes and overflows from roof tanks and service reservoirs. This is particularly true with older systems subject to high working pressures. Some saving here is also possible but limited.

It may be possible to reduce domestic and industrial demands by adopting a sliding scale of tariffs such that a minimum basic supply is provided cheaply to all consumers but that very high charges are levied for higher consumptions. Experience in Jordan and elsewhere suggests that this is of limited value in containing the expansion of demand.

In industry there is probably a need to encourage those processes which require only modest amounts of water in preference to those that are dependent on ample supplies. Lastly in the agricultural field it may well be necessary to pay greater attention to the development and greater production of crops less dependent on irrigation.

COMPETING DEMANDS

Clearly the economic value to be placed on the various supplies is a major consideration in the allocation of water in circumstances of restricted resources and competing demands. However it is not the only consideration that needs to be taken into account. In particular there is a need to assess the degree to which various proposals accord with the social and political strategies determined by the central government or other authorities. Frequently it is not possible to quantify these benefits which may include for example the maintenance of adequate social standards, improvements in health and the general quality of life and the provision of security in the supplies of food and water especially to the poorer sections of the population.

Since agriculture is the major water consumer in the country a further consideration is the sound planning of agricultural projects within the overall water use strategy so that the planned volume of water will continue to be available in the face of competing demands ensuring not only sound economic returns on investment but security of the social structure developed for its operation.

In spite of the difficulties inherent in assessing the benefits of a good water supply however, some policy guide must be established in order to attempt to make the best use to the country of the available water and to foresee well in advance those areas where a cut-back in water use might be desirable. It is necessary that in such a situation there should be a policy decision at an early stage to prevent the implementation of development schemes which might later have to be abandoned.

The value added to the nation for each unit of water used in irrigation varies with the region and understandably is less in desert areas than in the Jordan Valley or the highlands. For the Jordan Valley the net incremental benefit from irrigation, taking account of the cost of bringing water to the farms, is estimated at about 70 fils/m^3 in 1987 rising to about 180 fils/m^3 by the end of the century. A similar range is estimated for the highlands. These values are unusually high and reflect the ready market for the products with no surplus and also the high efficiencies aimed at by the Authority.

The value to industrial and commercial users is considerably higher. The net value added, for those projects looked at during the National Water Master Plan study ranges generally from 1000 to more than 3000 fils/m^3.

It is very difficult to assess the true benefit of water to the domestic consumer but some indication of this value is the amount he is prepared to pay for his supply.

Current water charges in the northern municipalities are around 110 fils/m^3 and those in the villages 125 fils/m^3 but these rates have not been increased for several years and in relation to current consumer purchasing power undoubtedly understate the real price the consumer would be prepared to pay.

In the case of Amman there is a recently revised sliding charge ranging from 60 to 225 fils/m^3. The estimates of domestic water demands have been established in the light of the available information on the consumer's ability to pay for water and on the assumption of an initial average charge of between 150 and 200 fils/m^3 with some further increase in real terms over time. The fact that some consumers in Amman are willing to pay marginal rates of charge of up to 225 fils/m^3 suggests that the real economic benefit to be derived from this consumption is in excess of 200 fils/m^3.

If it is argued that the domestic consumer is more able than the agricultural sector to meet higher charges it is worth looking at the marginal resources not already considered. The most obvious of these is desalination of sea water at Aqaba and its conveyance to North Jordan. The cost of such water at Aqaba, with conventional treatment would be in excess of 400 fils/m^3 and transport to Amman would raise this to about 700 fils/m^3.

Some economies might be achieved in the future by new processes, the most promising of these being the reverse osmosis process currently being developed and this should undoubtedly be included in future comparisons when its commercial use has been properly established. Even so there would appear to be no economic justification at present for exploiting such a resource.

A second option would be treatment of the highly saline waters of the Jordan river, so utilising water recovered from irrigation and deep seepage from the highlands. There are however no available records of river discharges and the current political situation makes this an unlikely solution to be considered at least for the present.

There is a certain mining potential which has not been included in the water resources and in economic terms the use of such resources may well be justified. Once these are depleted however the problem of allocation of reserves will arise even more urgently and for the purpose of long term strategy and of alerting the Authorities to the growing problem the use of fossil reserves has been discounted.

Generalities must be viewed with caution but from the available evidence the economic value to industrial users and to a lesser extent to domestic consumers is greater than to agriculture and if considered in this light only, suggests that, if there is to be a water constraint, preference should be given to industrial and municipal supplies.

There are undoubtedly social and political arguments for constraint in supplies also to the non-agricultural sector but as noted above the scope for reduction in demand is small. Industrial and commercial demands by 1987 are estimated to be 50 Mm^3/a rising to 97 Mm^3/a by the end of the century. This compares with estimated agricultural requirements which will rise to 637 Mm^3/a by 1987 and remain substantially constant until the year 2000. It is evident therefore that very substantial reductions in industrial supplies would make but a small difference in the amount of water available to agriculture.

In the domestic scene conditions are not dissimilar. Demands in 1987 are estimated at 96 Mm^3/a rising to 192 Mm^3/a by the end of the century and of these an appreciable proportion will in any case be re-used. There is therefore little scope for reductions on a scale that could be of real value to agriculture.

Consequently it is assumed in the following sections that industrial and domestic demands are met in full and the implications of shortfalls to agriculture are considered.

AMMAN-ZERQA: PRESENT SITUATION

As will be seen from Table 2 by far the greatest demand is and will continue to be from the Amman-Zerqa conurbation. The present demand is 71% of that for the whole of North Jordan but by 2002 this will have risen to 80%. Although the importance of supplies to other towns cannot be neglected, the water supply for Amman must be a major consideration in the strategic plan.

The present supply is drawn from the Amman-Zerqa aquifer systems and is exploited by wells along the bed of the wadi between Amman and Zerqa. The natural replenishable resource of this wellfield is estimated at 20 Mm^3/a as compared to a current abstraction of 30 Mm^3/a and even though there are indications that some recycling is in fact occurring the aquifer is being overpumped with consequent depletion of reserves.

There is a proposal to transfer water from the newly constructed King Talal reservoir and an abstraction of 12 Mm^3/a is planned as a first stage.

The present unrestricted domestic demand of the Amman-Zerqa area is 57 Mm^3/a rising to 107 Mm^3/a in ten years time. If this demand is to be satisfied then the next stage of source development should be capable of bringing the total supply up to not less than 100 Mm^3/a if further major capital works are not to be necessary in less than ten years. Furthermore if abstraction from the Amman-Zerqa wells is not to exceed the natural resource this infers the need for an incremental supply of 80 Mm^3/a. If advantage can be taken of re-use, the import of natural resources need however be only a proportion of this amount.

AMMAN-ZERQA: FUTURE SUPPLY

There are a number of options available for providing additional water supplies to the Amman-Zerqa area and these are summarised in Table 7 in order of the unit costs of water delivered to Amman (these costs exclude distribution)

TABLE 7 - Amman-Zerqa: Supply Options and Unit Costs of Water

Source	Gross Yield (Mm^3/a)	Losses (Mm^3/a)	Net Yield (Mm^3/a)	Unit Cost of Water ($fils/m^3$)
Amman-Zerqa wells	20	-	20 (1)	25
Dhuleil	20	-	20	72
Qastal	5	-	5	89
King Talal Dam	60	4 (2)	56 (1)	120
Rumeil Dam	18	6 (2)	12	128
Azraq	10	-	10	138
Maqarin	50	-	50 (3)	168
Zarqa Ma'in	20	4 (4)	16	258

Notes:-

1. The abstraction from the Amman-Zerqa wells and King Talal Dam will depend on the proportion of waste water recovered.
2. Evaporation from the reservoirs.
3. The potential of Maqarin Dam is greatly in excess of 50 Mm^3/a but this figure is adopted for the purpose of deriving unit costs.
4. Treatment losses.

It is quite clear that by far the most economical source of supply comes from the Amman-Zerqa wells and that abstraction from these ought to continue and be maximised to utilise as far as possible returned waste water.

The Dhuleil groundwater area is also a highly competitive source and if used in preference to King Talal or Maqarin Dams would permit water to be diverted to the Jordan Valley where the potential agricultural benefits are higher than those in the Dhuleil area. However this area was originally a re-settlement scheme augmented later by private development and is being extensively cultivated. The water resources are fully utilised mainly for agricultural purposes and indeed current abstraction is about 30 Mm^3/a and groundwater reserves are being depleted. Transfer of this water to Amman would therefore necessitate not only a cut-back in irrigated agriculture but would bring about considerable re-settlement costs, and social disruption which cannot readily be quantified.

Qastal groundwater is also economically attractive and there are at present no competing water requirements which cannot be supplied from an alternative source. However the modest yield of 5 Mm^3/a makes it of limited value since with demand increasing at a mean rate of 10 Mm^3/a each year the incremental supply would be overtaken by demand six months after commissioning. Moreover the area is geologically confused and extensive investigations would be necessary before the resources could be properly developed.

King Talal reservoir offers the most promising immediate solution. The natural replenishable yield is 60 Mm^3/a and it offers the important potential of water re-use within the Amman-Zerqa-King Talal Dam cycle. If the recovery of water were to amount to as much as 50% of the use, the natural resources necessary to satisfy requirements for the next ten years would be 50 Mm^3/a of which 20 Mm^3/a would come from the Amman-Zerqa aquifers and the balance of 30 Mm^3/a from the natural yield of the King Talal catchment. If these two sources are to be developed progressively to satisfy the requirements of the Amman-Zerqa conurbation and on the basis again of a 50% return to the cycle, the water resources of this area would be sufficient to satisfy demands up to the year 1992 by which time there would be no irrigation releases from King Talal Dam.

Next in ranking is the Rumeil Dam. This option would comprise a reservoir in the upper reaches of the Wadi Wala which would impound the erratic flood flows in the wadi. Storage would be relatively high possibly as much as 80 Mm^3 in order to provide the considerable carry-over necessary between floods. Although the hydrology is sufficiently known for preliminary yield estimates, because of the erratic nature of the run-off it would be necessary to allow storage of the first four to five year's run-off following commissioning of the project, which infers that eight to nine years must elapse from the decision to proceed with this scheme before the supply can be relied upon.

The Azraq Oasis is an area of discharge of groundwater which drains principally from the north. Groundwater is within 5 m of the surface over a large area and flows from two groups of springs and associated swamps. A body of very high salinity water lies near the surface under the playa and is exploited for salt extraction. Water from the better quality springs is pumped to Irbid for supplies to the city and its environment. The hydrogeological regime at Azraq is extremely complex both geologically and chemically as evidenced by the poor understanding of the area in spite of many studies in the past. The hydrogeological condition seems to be one of great delicacy and pumping from springs or boreholes could produce a variety of deleterious effects some of which could be irreversible. A comprehensive and expensive investigation would be necessary to reach a proper understanding of the regime before attempting to make full use of the resource available.

A further aspect of ecological importance is the major international significance of the oasis as a resting place on the bird migration route between paleartic regions and Africa and Azraq was selected as a designated conservation area when Jordan became a signatory nation of the Convention of Wetlands of International Importance in 1977. Major abstraction would dry up or considerably reduce springs and swamps and would thus radically alter surface conditions.

By far the greatest water resource in the whole country is the Yarmouk River at present being used extensively for irrigation and with an ambitious programme for further development. Water could be pumped directly from a river intake or from the Maqarin Dam scheduled soon for construction. The water quality is excellent.

Flow in the Zerqa Ma'in derives from springs emitting at a level of 125 m below sea level and flowing directly into the Dead Sea. The spring water is hot and very saline with TDS values of 1800 to 2000 mg/l. It is at present a tourist attraction and could remain so with its proper development as a water supply source. The use of the spring water for drinking would involve desalting. Because of the relatively small flood flow component only the base flow of 20 Mm^3/a would be exploited and of this about 4 Mm^3/a would be lost in the desalting process leaving a net yield of 16 Mm^3/a.

IRBID AND NORTHERN DISTRICT: PRESENT WATER SUPPLIES

The second most important town in North Jordan is Irbid which lies close to the Syrian border. The town is surrounded by a prosperous farming area and is an important administrative and commercial centre, much of the activity of the town being concerned with the marketing of produce and the provision of supplies to the adjacent areas.

The estimated domestic and industrial demands from the whole northern district is at present 16 Mm^3/a rising to 24 Mm^3/a in ten years time and to 40 Mm^3/a by the end of the century. Of this Irbid accounts for about 50%, Ramtha and Mafraq a further 20% with the balance distributed among the smaller townships and villages.

Present supplies come from wells at Ramtha, Sama Sdoud and Dhuleil and from the pools at Azraq. The water abstracted from these areas is then pumped to a collector station at Zaatri where a pumping station delivers the water to a service reservoir at Haufa. For some considerable time supplies to Irbid have been totally inadequate and although the recently installed additional capacity from Zaatri to Haufa has helped to a small degree, the source limitations have not been overcome and the total supplies for the whole of the northern district have been only about half of the unrestricted demands. There are longer terms proposals to abstract from the Yarmouk River at Maqarin Dam.

IRBID AND NORTHERN DISTRICT: FUTURE SUPPLIES

The options open for source supplies for Irbid and the northern district are few in number and comprise all the existing sources presently used, together with the Yarmouk. These are summarised in Table 8. Because of the nature of the development unit costs have been calculated for the delivery of water from Dhuleil, Sama Sdoud and Azraq to Zaatri pumping station and from Zaatri to Haufa. The unit costs of water from the Yarmouk cover the transmission from the dam to a service reservoir in the town.

TABLE 8 - Irbid and Northern District: Supply Options and Unit Costs of Water

Source	Delivery Point	Yield (Mm^3/a)	Unit Cost ($fils/m^3$)
Dhuleil	Zaatri	20	28
Sama Sdoud	"	8	55
Azraq	"	10	145
(Zaatri	Haufa	35 (1)	54)
Yarmouk	Irbid	38 (2)	118

Notes:-

(1) Zaatri is not a genuine 'source'.

(2) The yield of the Yarmouk is considerably in excess of the requirements for the whole northern district.

The most economical source is Dhuleil but as noted in the discussions for supplies to Amman there are serious social problems in depriving this area of substantial volumes of water. Since there will of necessity be a reduction in the present abstraction of over 30 Mm^3/a to the safe yield of 20 Mm^3/a at some time in the future it would appear that this whole amount should be allocated to the existing agricultural development and no allowance has been made for incorporating it into the long term plans for Irbid's supply.

The yield from Sama Sdoud is small but useful and in view of the low costs of water from this source its use should be continued but total abstraction limited to 8 Mm^3/a.

The problems and disadvantages of developing the Azraq Oasis for a water supply have already been discussed. Since the unit costs of delivering Azraq water only as far as Zaatri exceed that of water from the Yarmouk and since Azraq water can be exploited locally for agriculture preference has been given to use of the more economic source.

The total resources of the Yarmouk at Maqarin are considerably in excess of the requirements of the whole northern district and the hydrology of the system has been well studied and sufficient data are available for detailed planning purposes.

STRATEGY FOR WATER SUPPLY

We are now in a position to outline a strategy for the water supply of North Jordan up to the end of the century. Since water will have to be transported over considerable distances there are a number of sources in common so that supplying one area will have its effects on another and almost any abstraction will affect to a greater of lesser degree present or planned agricultural schemes.

Looking firstly at the supplies to Amman it is evident from Table 7 that the Amman-Zerqa wells should continue to be used. They provide a cheap and convenient means of exploiting the natural yield of 20 Mm^3/a and can be readily be located so as to intercept as far as possible the return waste water from Amman.

For reasons already discussed it is suggested that neither Dhuleil nor Qastal should be incorporated in the supply system.

King Talal Dam however provides an attractive next stage with a net yield of 56 Mm^3/a.

A proportion of the water used in Amman will ultimately return to the cycle and if this return is as high as say 50% a supply of 132 Mm^3/a could be provided from the combined resources of the Amman-Zerqa wells and King Talal dam. The effect of this on the demand pattern is illustrated schematically in Figure 3. The full exploitation of the water from the Amman-Zerqa aquifer by re-use will reduce the inflow into King Talal reservoir by 10 Mm^3/a thus reducing the net yield at the dam to 46 Mm^3/a.

Rumeil Dam could be incorporated into the system but because of the hydrological characteristics reservoir losses would be high and a net yield of 12 Mm^3/a is as much as could be relied upon. It is doubtful whether in fact the incorporation of this dam is justified.

Maqarin Dam would then be brought in to make up the deficit until the end of the century.

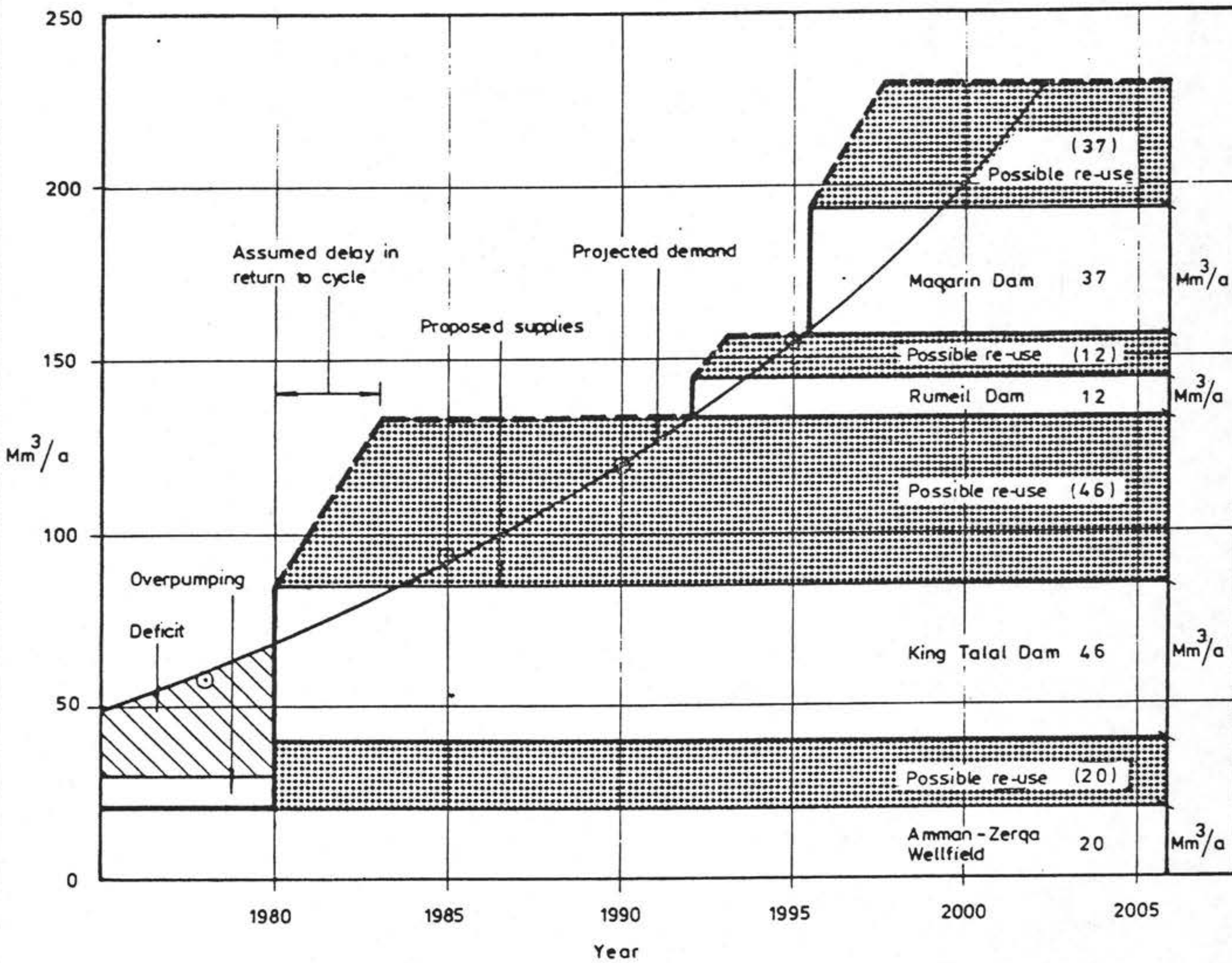
Abstraction from Zerqa Ma'in has also been considered but as already noted the salinity is too high for its use untreated. With the re-use of waste water in the Amman-Zerqa-King Talal Dam cycle the salinity would increase progressively although preliminary calculations show that demineralisation would not be necessary with the foregoing strategy provided the imports have a TDS not greatly in excess of 450 mg/l. Imports from Zerqa Ma'in would therefore require treatment and use of this source is consequently considerably more expensive than Maqarin.

Figure 3 must be read with caution; the actual re-use is not known nor is the delay between discharge of the waste water and its arrival in the system, particularly the groundwater component. However with the adoption of King Talal Dam as the next stage sufficient fresh water is available for at least another six years and during this period fullest use must be made of the time to monitor the behaviour of the water movements and to determine the characteristics of the regime so that any necessary modifications to the strategy can be made in good time.

It should be noted that these variations would merely alter the timing of the commissioning of the various stages but not the order in which they are brought into use.

Figure 3

SCHEMATIC DIAGRAM OF WATÈR SUPPLY STRATEGY FOR AMMAN-ZERQA CONURBATION



NOTES

1. Abstractions from King Talal Dam assumed to start in 1980
2. Timing indicated for commissioning new sources is based on 50% re use of all natural resources used in Amman. Actual re-use not known

In the northern district urgent additional supplies are necessary if the present demand is to be satisfied. The safe yield from Dhuleil is estimated at 20 Mm^3/a but at present 30 Mm^3/a is being abstracted of which 6 Mm^3/a is being transported to Irbid. The mining of this source will sooner or later have to be stopped so that insufficient water will be available even for present local requirements. The social problems associated with the change of use of this source have already been discussed and Dhuleil has been discounted as a water supply to Irbid.

Sama Sdoud should continue to supply the northern distribution system and its retention is assumed. We have already discussed the problems associated with the development of Azraq and since it provides a more expensive resource than Maqarin it is assumed that all future supplies will be abstracted from the Yarmouk River.

IMPLICATIONS ON AGRICULTURE

It is evident from the foregoing suggested strategy that Amman and the Northern District (comprising 85% of the total municipal requirements of North Jordan) will be heavily dependent on abstractions from the King Talal and Maqarin Dams both of which contribute to the ambitious irrigation programme of the Jordan Valley Authority and it is therefore necessary to look at the technical and economic consequences of such a strategy.

King Talal Dam was built expressly for the purpose of irrigating the Zerqa Triangle lying between the dam and the East Ghor with the surplus waters destined for an extension of the irrigation southwards. With increasing transference of water from the reservoir to Amman the surplus water available for irrigation would be correspondingly decreased. In the early stages this would merely result in there being no surplus for the extended irrigation but as the rate of abstraction increased the Zerqa Triangle would ultimately be deprived. This shortfall could be made up by pumping from the East Ghor to the head of the Triangle.

This in turn would mean that areas originally planned to be irrigated from the River Zerqa would then be supplied from the Yarmouk so that additional storage on the Yarmouk River would be necessary to compensate for the loss of water from King Talal reservoir. Similarly as water is abstracted from the Yarmouk to supply Irbid and the northern district further provision would need to be made at Maqarin to store this water for domestic use.

Since agriculture and domestic consumers would be competing for the same source and since there will be insufficient resources to satisfy both, an additional factor to consider is the loss to agriculture should it be deprived of its irrigation water. The unit costs summarised in Tables 7 and 8 already make an allowance for the additional storage required but in order to assess the real value of water to Amman for example these unit rates should be increased not only by the cost of lifting water into the Zerqa Triangle but also by the net loss to agriculture in the valley by reducing the available irrigation water.

The true cost of water to Amman would thus exceed 300 fils/m^3 and it is important that tariff structures should be designed to reflect this in order to achieve a proper, realistic, economic balance between agriculture on one hand and domestic and industrial requirements on the other hand. Such a cost should also be used as a basis of comparison with other marginal sources.

CENTRAL AUTHORITY

It is not the purpose of this paper to discuss the organisation necessary to administer and control water abstraction and use but it would be incomplete without some reference to this important aspect. While there are surplus reserves the problems of alternative uses of water are not serious. However when there are strong competing interests it is important to have a central authority with access to all the political, social and economic aspects which can, without prejudice, allocate resources in the best interest of the nation as a whole. Such an authority would also ensure continuing investigations not on a project basis but in order to assemble data which would complete the general knowledge of all resources within the country. It would also be responsible for the control of catchments both surface and sub-surface and in particular of those where waste water re-use is proposed. Particular care is necessary to control the discharge of industrial waste which could seriously pollute the water supplies. The authority would also control abstraction from whatever source, avoid over pumping of groundwater and the intrusion of saline fronts and also ensure that mining is carried out as a properly formulated policy and not as a short term convenience.

The difficulties to be faced by such an authority are fully realised but the time is now fast approaching when such an organisation is necessary in the interests of Jordan.